23.3 (CONT)

$$3V_{IH}^2 - 6V_{IH} - 3V_{IH} + 6 - 2\left(\frac{9}{16}V_{IH}^2 - \frac{9}{4}V_{IH} + \frac{9}{4}\right) = 16 - 8V_{IH} + V_{IH}^2$$

$$V_{IH}^2\left(3 - \frac{9}{8} - 1\right) + V_{IH}\left(-6 - 3 + \frac{9}{2} + 8\right) + \left(6 - \frac{9}{2} - 16\right) = 0$$

$$V_{IH}^2(0.875) + V_{IH}(3.5) - 14.5 = 0$$

$$V_{IH}^2 + 4\,V_{IH} - 16.6 = 0$$

$$\therefore V_{IH} = -\frac{4}{2} + \frac{\sqrt{(4)^2 + 4(16.6)}}{2} = -2 + 4.54 = 2.54\,V$$

V_M:

$$V_M = \left[V_{DD} + V_{TP} + V_{TN}\sqrt{\frac{k_N}{k_P}}\right] \Big/ \left[1 + \sqrt{\frac{k_N}{k_P}}\right]$$

$$= \left[5 + (-1) + 1\sqrt{\frac{100}{50}}\right] \Big/ \left[1 + \sqrt{\frac{100}{50}}\right] = \frac{5.4142}{2.416}$$

$$= 2.24\,V$$

$$V_{NMH} = V_{OH} - V_{IH} = 5 - 2.54 = 2.46\,V$$

$$V_{NML} = V_{IL} - V_{OL} = 1.79 - 0 = 1.79\,V$$

23.4 GRAPHICAL DETERMINATION OF CRITICAL VOLTAGES

$V_{DD} = 10V$

$I_{D,N}(SAT) = 50\mu(V_{IN} - 1)^2$ UNCHANGED FROM PROBLEM 23.2

$$I_{D,P}(SAT) = \frac{50}{2}\left(V_{GS,P} + V_T\right)^2 = 25\mu\left(10 - V_{IN} - 1\right)^2$$

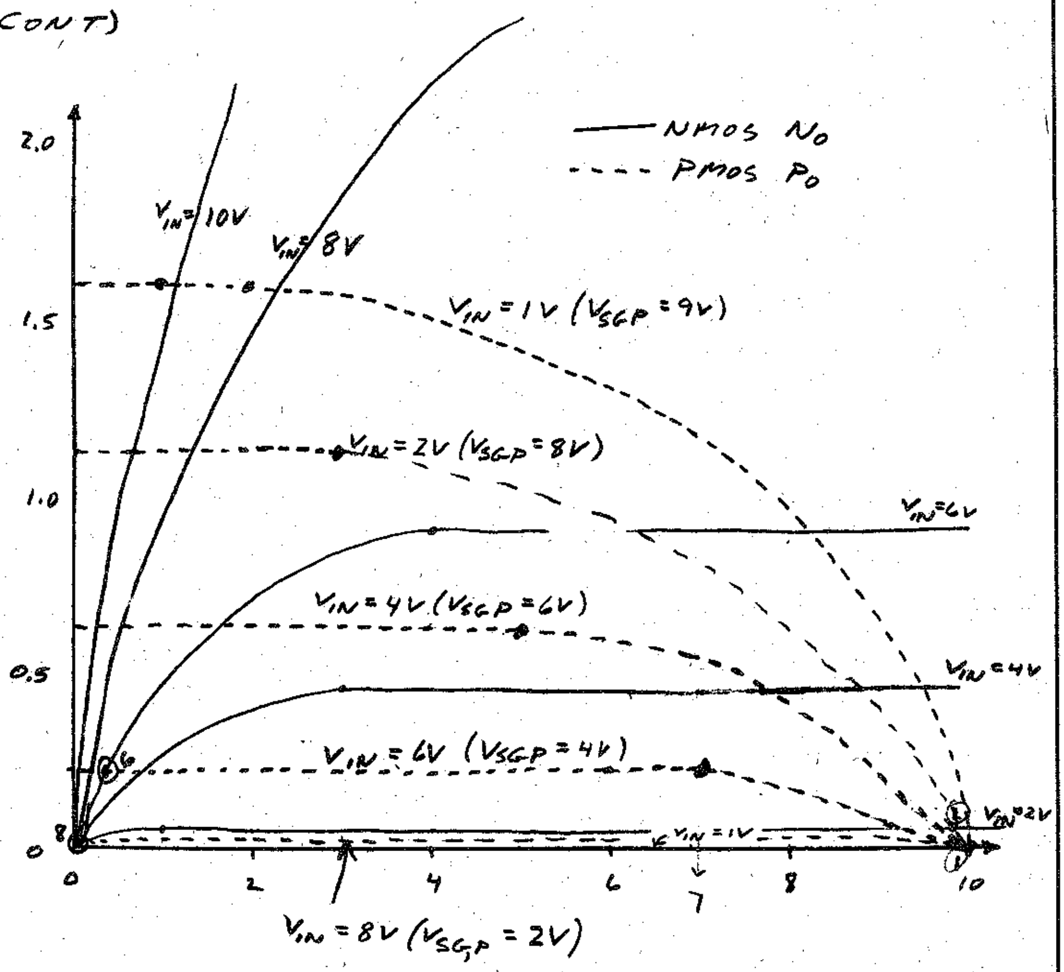
$$I_{D,P}(SAT) = 25\mu(9 - V_{IN})^2$$

V_{IN}	$I_{DN}^{(SAT)}$
1	0
2	0.05
4	0.45
6	0.8
8	2.45
10	4.05

V_{IN}	$I_{D,P}(SAT)$ mA	$V_{SGP} = (10 - V_{IN})$
1	1.6	9
2	1.225	8
4	0.625	6
6	0.225	4
8	0.025	2
9	0	1 ← V_T

IV CHARACTERISTICS ON NEXT PAGE

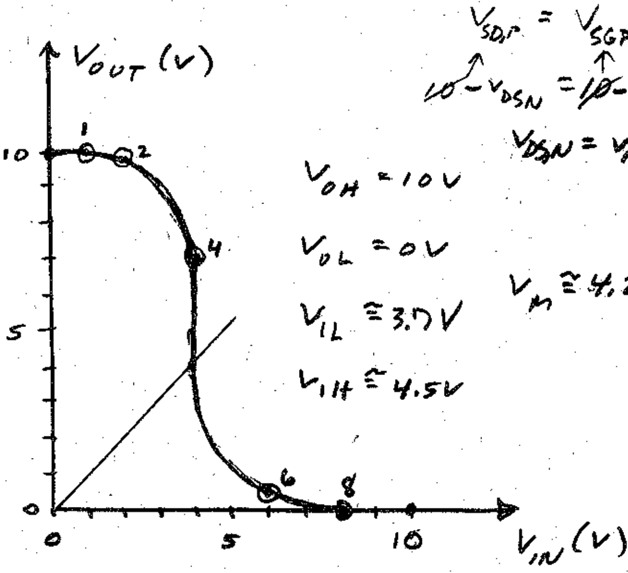
23.4 (CONT)



$$V_{SD,P} = V_{SGP} + V_{TP} = V_{SGP} - 1$$

$$10 - V_{DSN} = \cancel{10} - V_{IN} + V_{T,P}$$

$$V_{DSN} = V_{IN} - V_{T,P}$$



$V_{OH} = 10V$

$V_{OL} = 0V$

$V_{IL} \cong 3.7V$

$V_{IH} \cong 4.5V$

$V_M \cong 4.2V$

24.11 BY INSPECTION OF THE CIRCUIT

$$F = \overline{A\bar{B} + \bar{A}B} = (\bar{A}+B)(A+\bar{B}) = \bar{A}\bar{B} + AB \quad \text{XNOR}$$

24.12 XOR

24.13 THE RELATION FOR W/L RATIOS FOR CMOS NAND GATES WITH m INPUTS IS

$$2.5\left(\frac{W}{mL}\right)_N = \left(\frac{W}{L}\right)_P$$

THUS, FOR A 2 INPUT NAND gate

$$\frac{2.5}{2}\left(\frac{W}{L}\right)_N = \left(\frac{W}{L}\right)_P$$

CASE A: CHOOSE MINIMUM SIZE NMOSFETs

$$\left(\frac{W}{L}\right)_N = \frac{4\mu m}{2\mu m}$$

AND THUS

$$\left(\frac{W}{L}\right)_P = \left(\frac{4\mu}{2\mu}\right)\left(\frac{2.5}{2}\right) = \frac{5\mu}{2\mu}$$

FOR THIS CASE THE CHIP AREA FOR THE 4 TRANSISTORS IS

$$AREA = 2(A_N + A_P) = 2(4\times 2 + 5\times 2) = 36\,\mu m^2$$

CASE B CHOOSE MINIMUM SIZE PMOSFETS

$$\left(\frac{W}{L}\right)_P = \frac{4\mu}{2\mu}$$

THUS,

$$\left(\frac{W}{L}\right)_N = \left(\frac{4}{2}\right)\left(\frac{2}{2.5}\right) = \frac{4\mu}{2.5\mu} = \frac{3.2\mu}{2\mu}$$

AND

$$AREA = 2(4\times 2 + 3.2\times 2) = 28.8\,\mu m^2$$

25.6)

	V_{IN}	N_n	P_n	PULL-UP PATH	PULL-DOWN PATH	V_{OUT}
1.	LOW	OFF	ON	YES	NO	HIGH
2.	HIGH	ON	OFF	NO	YES	LOW
3.	Z	?	?	NO	NO	Z
4.	X	?	?	YES	YES	X

25.7) EQUATE THE LINEAR DRAIN CURRENTS FOR THE N- AND P- CHANNEL MOSFETS:

$$I_{D,N}\,(LIN) = I_{D,P}\,(LIN)$$

$$k_N\left[(V_{GS,N} - V_{TN})V_{DS,N} - \frac{V_{DS,N}^2}{2}\right] = k_P\left[(V_{SG,P} + V_{T,P})V_{SD,P} - \frac{V_{SD,P}^2}{2}\right]$$

SUBSTITUTE:

$$V_{GS,N} = V_{INA} = V_{OH} = 5V$$

$$V_{SG,P} = V_{DD} - V_{INB} = V_{DD} - V_{OL} = 5V$$

$$V_{DS,N} = V_{OUT}$$

$$V_{SD,P} = V_{DD} - V_{OUT}$$

$$80\mu\left[(5-1)V_{OUT} - \frac{V_{OUT}^2}{2}\right] = 80\mu\left[(5+(-1))(5 - V_{OUT}) - \frac{(5-V_{OUT})^2}{2}\right]$$

$$4V_{OUT} - \frac{\cancel{V_{OUT}^2}}{2} = 20 - 4V_{OUT} - \frac{25}{2} + 5V_{OUT} - \frac{\cancel{V_{OUT}^2}}{2} \longrightarrow 3V_{OUT} = 20 - \frac{25}{2} = 7.5$$

COLLECT LIKE TERMS AND SOLVE FOR V_{OUT}:

$$V_{OUT} = 2.5V = V_X$$

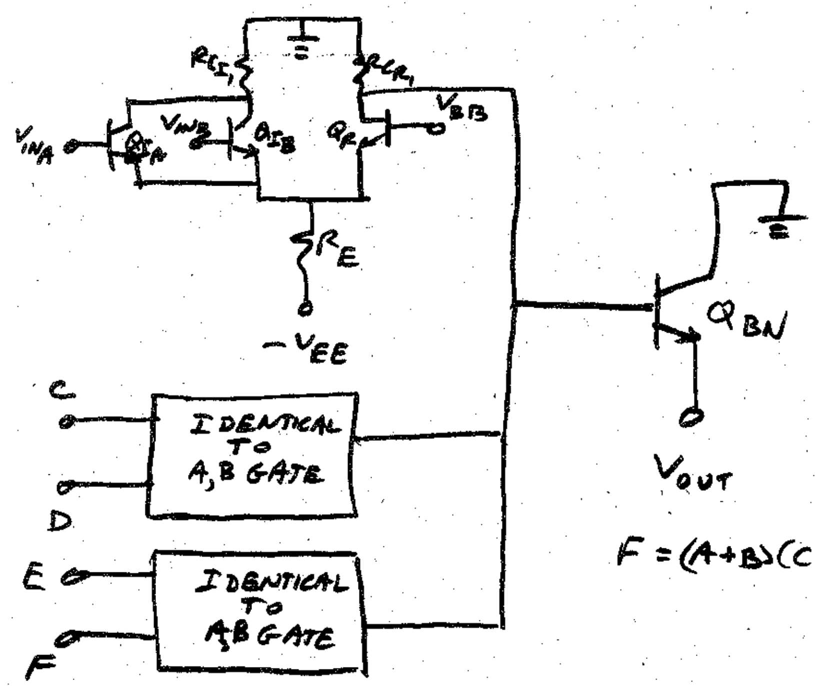
25.8

V_A	$V_B = V_C$	V_{OUT}
Low	Low	V_{DD}
Low	Hi	Low
Hi	Low	Low
Hi	Hi	Low

25.9

V_{IN}	$\overline{V_{PEN}}$	V_{NEN}	V_{TINV}
Low	Low	Low	Hi
Low	Low	Hi	Hi
Low	Hi	Low	X
Low	Hi	Hi	X
Hi	Low	Low	X
Hi	Low	Hi	Low
Hi	Hi	Low	X
Hi	Hi	Hi	Low

15.11 REALIZE THE LOGIC FUNCTION $F=(A+B)(C+D)(E+F)$



$F=(A+B)(C+D)(E+F)$

15.12 TO OBTAIN THE INVERSE OF F, FROM PROBLEM 15.11, $\overline{F}=\overline{(A+B)(C+D)(E+F)}$
USE SAME CIRCUIT AS PROBLEM 15.11 EXCEPT COLLECTOR DOTTINF OF INPUT TRANSISTOR COLLECTORS WITH OUTPUT BUFFER BJT QBINV.

15.13

A	B	XOR
0	0	0
0	1	1
1	0	1
1	1	0

15.14

A	B	XNOR
0	0	1
0	1	0
1	0	0
1	1	1

26.10 TWICE THE DRIVE STRENGTH IMPLIES THAT THE W/L RATIOS OF THE DEVICES IN THE STACK SHOULD BE DOUBLED THUS,

$$\frac{W_{NO}}{L_{NO}} = \frac{W_{NI}}{L_{NI}} = 2\left(\frac{8\mu m}{2\mu m}\right) = 8$$

AND

$$\frac{W_{PO}}{L_{PO}} = \frac{W_{PI}}{L_{PI}} = 2\left(\frac{20\mu m}{2\mu m}\right) = 20$$

HENCE

$$k_{NI} = k_{NO} = k'_{NI}\frac{W_{NI}}{L_{NI}} = 40\mu(8) = 320\mu A/V^2$$

$$k_{PI} = k_{PO} = k'_{PI}\frac{W_{PI}}{L_{PI}} = 16\mu(20) = 320\mu A/V^2$$

ALSO

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{V_{ID} - V_{TN}}{V_{DD} - V_{ID}}\right]^2 \frac{W_{NI}}{L_{NI}} = \left[\frac{4-1}{5-4}\right]^2 8 = 72$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{V_{DD} + V_{TP} - V_{IU}}{V_{IU}}\right]^2 \frac{W_{PI}}{L_{PI}} = \left[\frac{5-1-1}{1}\right]^2 20 = 180$$

26.11 USING THE EQS OF THE PREVIOUS PROBLEM (26.10)

$$\frac{W_{NO}}{L_{NO}} = \frac{W_{NI}}{L_{NI}} = 2\ \frac{8\mu m}{2\mu m} = 8 \text{ AND } \frac{W_{PO}}{L_{PO}} = \frac{W_{PI}}{L_{PI}} = 2\ \frac{20\mu m}{2\mu m} = 20$$

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{4-1}{7-4}\right]^2 8 = 8$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{7-1-1}{1}\right]^2 20 = 25(20) = 500$$

26.12 USING THE EQS OF THE PREVIOUS PROBLEMS

SAME RESULTS FOR N_O, P_O, N_I, P_I. THEN

$$\frac{W_{NF}}{L_{NF}} = \left[\frac{4-1}{10-4}\right]^2 8 = \left[\frac{1}{4}\right] 8 = 2$$

$$\frac{W_{PF}}{L_{PF}} = \left[\frac{10-1-1}{1}\right]^2 20 = 64(20) = 1280$$

27.4 (CONT)

For the third stage:

$k_{N_3} = k_{P_3} = k_N'(W/L)_{N_3} = 40\mu(120/2) = 2.4\,mA/V^2$

$C_{L3} = [(WL)_{N_4} + (WL)_{P_4}]C_{ox} = [1750\times2 + 700\times2]\,690a$

$= (3500 + 1400)\,690 = 3.38\,pF$

$\tau_{P_3} = AC_{L3}/k_{P3} = \dfrac{0.322\times 3.38p}{2.4m} = 0.45\,nS$

For the Fourth stage:

$k_{N_4} = k_{P_4} = (40\mu)(700/2) = 14\,mA/V^2$

$C_{L4} = C_L = 5pF$

$\tau_{P4} = \dfrac{0.322\,(5p)}{14m} = 0.115\,nS$

$\tau_{P_{TOTAL}} = 0.39 + 0.47 + 0.45 + 0.115 = 1.425\,nS$

27.5 ALL k_N and $k_P \times \dfrac{1000}{690}$ and ALL $C_{IN} \times \dfrac{1000}{690}$

$\therefore$ ALL τ unchanged except τ_4

27.6 Transconductance Parameters doubled

From Problem 27.4:

$A = B = 0.322/V$, $k_{P_1} = 160\mu A/V^2$, $C_{L_1} = 96.6\,fF$

$\tau_{P_1} = \dfrac{0.322\,(96.6f)}{160\mu} = \dfrac{0.39}{2} = 0.195\,nS$

For the second stage

$\tau_{P_2} = AC_{L2}/k_{P_2} = 0.47/2 = 0.235\,nS$

For the 3rd Stage

$\tau_{P_3} = AC_{L3}/k_{P3} = 0.45/2 = 0.225\,nS$

For the 4th stage $\tau_{P4} = \dfrac{0.115}{2} = 0.0575\,nS$

$\therefore \tau_{TOTAL} = 0.7125\,nS$

PRODUCED DUE TO THE LARGE GATE CURRENT, THE FANOUT AND RELIABILITY OF THE GATE ALSO BECOME UNACCEPTABLE.

34.6 $a = 0.1\ \mu m$ $\quad \beta' =$ PROCESS TRANSCONDUCTANCE

$W = 0.6\ \mu m$ $\quad \beta =$ DEVICE TRANSCONDUCTANCE

$L = 3.0\ \mu m$

$$\beta' = \frac{\mu_N \epsilon_{GaAs}}{2a} = \frac{8600\ \frac{cm^2}{V\text{-}s} \times 1.16 \times 10^{-12}\ F/cm}{2 \times 10^{-5}\ cm}$$

$$\therefore \boxed{\beta' = 498.8\ \mu A/V^2} \boxed{\doteq 500\ \mu A/V^2}$$

$$\beta = \beta' \cdot W/L = 498.8 \times \frac{0.6}{3.0} = 99.76\ \mu A/V^2$$

$$\therefore \boxed{\beta = 99.76\ \mu A/V^2} \boxed{\doteq 100\ \mu A/V^2}$$

34.7

$$V_P = \frac{qN_D a^2}{2\epsilon_{GaAs}} \qquad N_D = 10^{17}/cm^3$$

$$= \frac{1.6 \times 10^{-19} \times 10^{17} \times 10^{-5}}{2 \times 1.16 \times 10^{-12}}$$

$$\boxed{V_P = 0.69\ V}$$

$$V_T = V_{bi} - V_P$$
$$= 0.8 - 0.69$$
$$= 0.11\ V$$

$$\boxed{V_T = 0.11\ V}$$

35.7

a) $V_{OH} = V_{SBD,GaAs}(ON) = 0.8\,V$

$\boxed{V_{OH} = 0.8\ V}$

$$V_{IL} = V_{T,0} + |V_{T,L}| \left[\frac{\beta_L[1+\lambda_L(V_{DD} - V_{SBD,GaAs})] \tanh \alpha_L (V_{DD} - V_{SBD,GaAs})}{\beta_0 (1 + \lambda_0 V_{SBD,GaAs}) \tanh \alpha_0 V_{SBD,GaAs}} \right]^{1/2}$$

$$= 0.2 + |-1| \left[\frac{1}{10} \frac{\tanh 2(0.2)}{\tanh 2(0.8)} \right]^{1/2} = 0.2 + 0.2$$

$\boxed{V_{IL} = 0.4\ V}$

$$V_{OL} = \frac{1}{\alpha_0} \cdot \frac{\beta_L}{\beta_0} \frac{V_{T,L}^2}{(V_{OH} - V_{T,0})^2} \cdot (1 + \lambda_L \cdot V_{DD}) = \frac{1}{2} \frac{1}{10} \frac{(-1)^2}{(0.8-0.2)^2}$$

$\boxed{V_{OL} = 0.139\ V}\ \boxed{= 0.14\,V}$

FOR DETERMINATION OF VIH, NUMERICAL SOLUTION OF TWO EQUATIONS, AS IN PROBLEM 35.2, IS REQUIRED. STARTING WITH A GUESS VALUE FOR EACH OF VIN i.e. VIH AND VOUT, SOLUTION CAN BE WORKED OUT ON MATHCAD.

$V_{OUT} = 0.22\ V$

$\boxed{V_{IH} = 0.69\ V}$ SEE NEXT PAGE FOR DETAILS

$V_{NMH} = V_{OH} - V_{IH} = \boxed{0.11\ V}$

$V_{NML} = V_{IL} - V_{OL} = \boxed{0.26\ V}$

b) DIRECT SUBSTITUTION IN TO THE EXPRESSIONS AS IN 35.5 GIVES

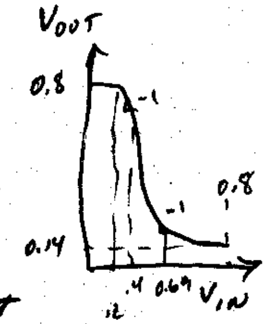
$I_{DD}(OH) = 88.535\ \mu A \leftarrow \beta_L V_{T,L}^2 (1 + \lambda_L(V_{DD} - V_{OH})) \tanh \alpha_L (V_{DD} - V_{OH})$ $100\,(-1)^2(1 + 0\,(0.7)) \tanh 2(0.7)$

$I_{DD}(OL) = 99.14\ \mu A \leftarrow 100\,(-1)^2 \tanh 2(1.5 - 0.14)$

$$P_{DD} = \frac{(88.535 + 99.14)}{2} \cdot (1.5)$$

$\boxed{P_{DD} = 140.8\ \mu W}$

35.7 Determination of V_{IH}



(1) $V_{IH} = 0.2 + \dfrac{1}{\sqrt{10 \tanh 2V_{out}}}$

(2) $V_{IH} = 0.2 + \cosh^2 2V_{out} \tanh 2V_{out}$

Equate

$$0.316 = \frac{1}{\sqrt{10}} = \cosh^2 2V_{out} \tanh^{3/2} 2V_{out}$$

choose $2V_{out}$	Calculate $\cosh^2(2V_{out})(\tanh^{3/2}(2V_{out})) =$
0.22	$(1.0492)(1.007) = 0.1$
0.4	$(1.169)(0.234) = 0.274$
0.38	$(1.151)(0.218) = 0.25$
0.5	$(1.271)(0.314) = 0.4$
0.45	$(1.217)(0.274) = 0.33$
0.44	$(1.21)(.266) = 0.32$

$\therefore \underline{2V_{OUT} \cong 0.44\,V} \rightarrow V_{OUT} = 0.22$

$$V_{IH} = 0.2 + \cosh^2(0.44)\tanh(0.44)$$

$$= 0.2 + \underbrace{(1.206)(0.41)}_{0.49} = \underline{0.69\ V}$$

as a check

$$V_{IH} = 0.2 + \frac{1}{\sqrt{10 \tanh 0.44}} = 0.2 + .49 = 0.69$$

c) MAXIMUM FANOUT

MAXIMUM FANOUT IS OBTAINED FOR $V_{OUT} = V_{IH}$

$$I_{D,L} = \beta_L V_{T,L}^2 \cdot \tanh(\alpha_L (V_{DD} - V_{IH}))(1 + \lambda_L (V_{DD} - V_{IH}))$$

$$= 92.34 \ \mu A$$

$$I'_{G,0}(IH) = I_{SBD} \cdot \exp\left[\frac{V_{IH}}{0.026}\right] = (10^{-12} \mu A)\left(\exp\left[\frac{0.69}{0.026}\right]\right)$$

$$= 0.335 \ \mu A$$

$$N = \frac{I_{D,L}}{I'_{G,0}(IH)} = 275.64$$

$$\boxed{N_{MAX} = 275}$$

FANOUT FOR $NM_H = 0.1$ V

$$V_{OUT} = \overset{0.69}{V_{IH}} + \overset{0.1}{NM_H}$$

$$V_{OUT} = 0.79$$

$$I_{D,L\,(V_{OUT}=0.79)} = \beta_L \cdot V_{T,L}^2 \cdot \tanh[\alpha_L (V_{DD} - V_{OUT})(1 + \lambda_L (V_{DD} - V_{OUT}))$$

$$= 88.809 \ \mu A$$

$$I'_{G0\,(V_{OUT}=0.794)} = (I_{SBD}) \cdot \exp(\overset{.79}{V_{OUT}}/0.026)$$

$$= 15.6 \ \mu A$$

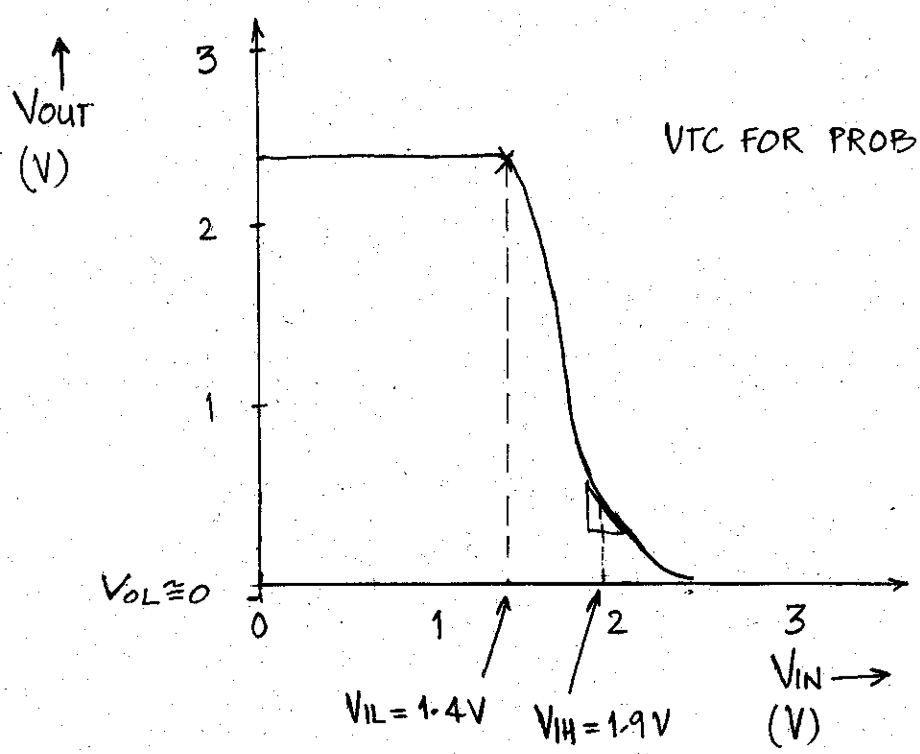
$$N = I_{D,L} / I'_{G0}$$

$$= 5.69$$

$$\boxed{N = 5}$$

$$V_{IH} = 1.4 + (0.32)\tanh^{-1/2}(0.426)$$
$$= 1.4 + 0.5$$
$$\boxed{V_{IH} = 1.9\ V}$$

$$V_{NML} = V_{IL} - V_{OL} = 1.4 - 0.05 = 1.35\ V$$
$$V_{NMH} = V_{OH} - V_{IH} = 2.4 - 1.9 = 0.5\ V$$



VTC FOR PROB 36.2

36.3

AVERAGE POWER DISSIPATION

$$P_{DISS} = I_{DD} \cdot V_{DD} + I_{SS} \cdot V_{SS}$$

WHERE $I_{DD} = \dfrac{I_{DD}(OH) + I_{DD}(OL)}{2}$

$I_{SS} = \dfrac{I_{SS}(OH) + I_{SS}(OL)}{2}$

36.3 (CONT)

$$I_{DD}(OL) = I_{DL}(OL) = \beta_L V_{T,L}^2 (1+\lambda_L(V_{DD}-V_{OL}))$$

$$= \left(\frac{100}{10}\right)(-1)^2(1+0.2(3-0.05))$$

$$= 10\ (1+0.59) = \underline{15.9\mu A}$$

$$I_{DD}(OH) = \beta_L V_{T,L}^2 (1+\lambda_L V_{DS,L}) \tanh \alpha_L V_{DS,L}$$

$$= \left(\frac{100}{10}\right)(-1)^2(1+0.2(3-2.4)) \underbrace{\tanh \overbrace{2(3-2.4)}^{1.2}}_{0.83}$$

$$= 10\ (1+0.12)(0.83)$$

$$= \underline{9.3\mu A}$$

$$I_{SS}(OL) = \beta_D V_{T,D}^2 (1+\lambda_D(V_{OH} - 3V_{SBD\,GaAs}(ON) + V_{SS}))$$

$$= 100\,(-1)^2(1+0.2(2.4-2.4-(-3)))$$

$$= 100\ (1+0.6) = \underline{160\mu A}$$

$$I_{SS}(OH) = \beta_D V_{T,L}^2 (1+\lambda_D(V_{OL} - 3V_{SBD\,GaAs}(ON) + V_{SS})) \tanh \alpha_D V_{DS,L}$$

$$= 100(-1)^2(1+0.2(0.05-2.4+3)) \tanh 2(0.65)$$

$$= 100\ (1+0.2(0.65))(0.86) = \underline{97.2\mu A}$$

$$P_{DISS}(AV) = V_{DD} I_{DD} + V_{SS} I_{SS} = 3\left(\frac{15.9+9.3}{2}\right) + 3\left(\frac{160+97.2}{2}\right)$$

$$= 37.8 + 386 = 423.8\mu W$$

$$= 0.42\,mW$$

37.4 a)

$V_{OH} = V_{DD} - 3V_{SBD,GaAs(ON)} = \boxed{0.6V}$

$V_{IL} = V_{T,0} = \boxed{-1.5V}$

$V_{OL} = -3V_{SBD,GaAs(ON)} = \boxed{-2.4V}$

THE FOLLOWING EXPRESSIONS ARE NUMERICALLY SOLVED FOR V_{IH}

$$\beta_L \cdot V_{T,L}^2 \tanh\alpha_L \cdot V_{DS,L} \cong \beta_0 (V_{IN} - V_{T,0})^2 \tanh\alpha_0 V_{DS,0} + \beta_C \cdot V_{T,C}^2 - \beta_F (V_{GS,F} - V_{T,0})^2$$

AND

$$\frac{\alpha_L \cdot V_{T,L}^2}{\cosh^2\alpha_L \cdot V_{DS,L}} + \frac{(\beta_0/\beta_L)\alpha_L \cdot (V_{IN} - V_{T,0})^2}{\cosh^2\alpha_0 \cdot V_{DS,0}} = 2\frac{\beta_0}{\beta_L}(V_{IN} - V_{T,0}) \tanh\alpha_0 \cdot V_{DS,0}$$

WHERE $V_{DS,L} = V_{DD} - [V_{OUT} + 3V_{SBD,GaAs(ON)}]$

$V_{DS,0} = V_{OUT} + 3V_{SBD,GaAs(ON)}$

WE GET,

$V_{OUT} = -1.95V$ AND $\boxed{V_{IH} = -0.05V}$ SEE NEXT PAGE

AND,

$V_{NMH} = V_{OH} - V_{IH}$ AND $V_{NML} = V_{IL} - V_{OL}$

$V_{NMH} = 0.65V$ $V_{NML} = -1.5 + 2.4 = 0.9V$

b) $I_{SS}(OL) = \overset{(100)}{\beta_C} \cdot \overset{(1.5)^2}{V_{T,C}^2} [1 + \overset{(0)}{\lambda_C}(V_{OL} + V_{SS})] \cdot \tanh[\underbrace{\alpha_C (V_{OL} + V_{SS})}_{2(-2.4+3)}]$

$= 187.6\mu A$

$I_{SS}(OH) = \underset{(100)}{\beta_C} \cdot \underset{(1.5)^2}{V_{T,C}^2} [1 + \overset{0}{\lambda_C}(V_{OH} + V_{SS})] \cdot \overset{1}{\tanh}[\underbrace{\alpha_C (V_{OH} + V_{SS})}_{2(0.6+3)}]$

$= 225\mu A$

$I_{SS} = (I_{SS(OL)} + I_{SS(OH)})/2 = 206.3\mu A$

$I_{DD}(OL) = I_{D,L}(OL) + I_{D,F}(OL)$

$= \underset{50}{\beta_L} \cdot \underset{(1.5)^2}{V_{T,L}^2} (1 + \lambda_L \cdot V_{DD}) \cdot \overset{1}{\tanh}\alpha_L \cdot V_{DD} + \underset{50}{\beta_F} \overset{(0.8+1.5)^2}{(V_{GS,F} - V_{T,F})^2} \cdot \{1 + \lambda_F \cdot V_1\} \cdot \overset{1}{\tanh}\alpha_F \cdot V_1$

WHERE $V_1 = V_{DD} + V_{SBD,GaAs(ON)}$

$= 377\mu A$

$I_{DD}(OH) = I_{SS}(OH) = 225\mu A$

$I_{DD} = (I_{DD}(OL) + I_{DD}(OH))/2 = 301\mu A$

$P_{DISS} = V_{DD} \cdot I_{DD} + V_{SS} \cdot I_{SS} = \boxed{1.522 mW}$

37.4 (CONT)

V_{IH}: 2 EQUATIONS

$$(1)\ \cancel{50}^{1}(-1.5)^2\cancel{\tanh}\,2(0.6-V_{OUT}) = \cancel{100}^{2}(V_{IN}+1.5)^2\tanh 2(V_{out}+2.4) + \cancel{100}^{2}(1.5)^2 - \cancel{50}(0.8+1.5)^2$$

$$(-1.5)^2 = 2(V_{IN}+1.5)^2\tanh \underbrace{2(V_{out}+2.4)}_{x} + 2(2.25) - (2.3)^2$$

$$2.25 - 4.5 + 5.25 = 2(V_{IN}+1.5)^2\tanh(x)$$

$$3 = 2(V_{IN}+1.5)^2\tanh(x)$$

$$(1)\quad V_{IN}+1.5 = \sqrt{\frac{3}{2}\frac{1}{\tanh(x)}} = \frac{1.225}{\tanh^{1/2}(x)}$$

$$(2)\quad \frac{2(-1.5)^2(\quad)}{\cosh^2 2\underbrace{(0.6-V_{out})}_{(large>1)}} + \left(\frac{100}{50}\right)\frac{2(V_{IN}+1.5)^2}{\cosh^2 \underbrace{2(V_{OUT}+2.4)}_{x}} = 2\left(\frac{100}{50}\right)(V_{IN}+1.5)\tanh(x)$$

$\overset{\sim}{=} 0$

$$(2)\quad V_{IN}+1.5 = \cosh^2 x\,\tanh x$$

where $x = 2(V_{OUT}+2.4)$

Equate (1) & (2) $\quad \dfrac{1.225}{\tanh^{1/2}x} = \cosh^2 x\,\tanh x$

or $\quad 1.225 = \cosh^2 x\,\tanh^{3/2} x$

choose x	Calculate $\cosh^2 x \tanh^{3/2} x$
1	$2.381 \times 0.665 = 1.58$
0.85	$1.914 \times 0.574 = 1.1$
0.9	$2.054 \times 0.6 = 1.25$ close enough

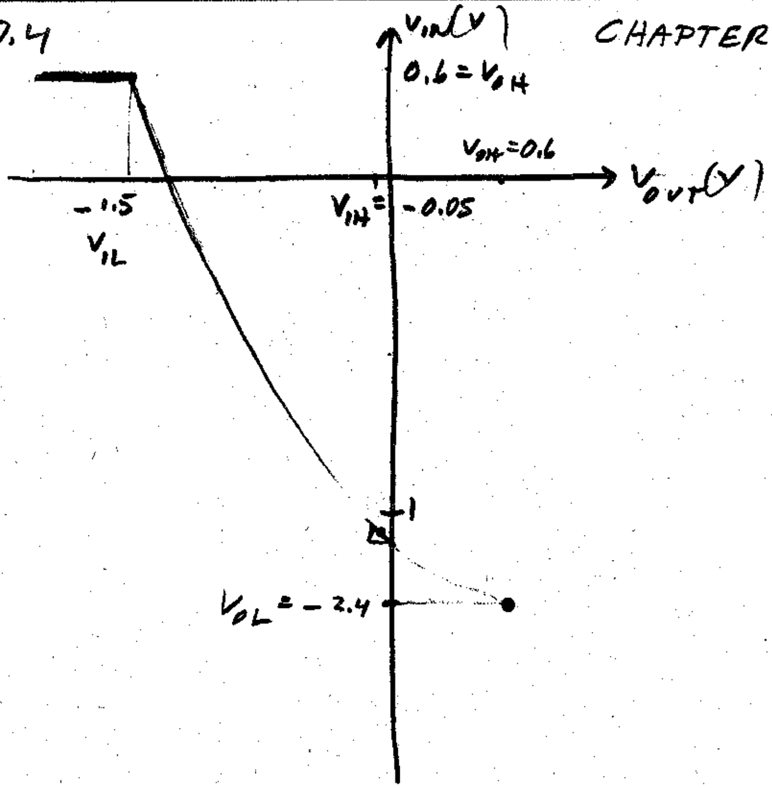
$\therefore\ x = 0.9 = 2(V_{out}+2.4) \rightarrow V_{OUT} = -1.95\text{V}$

Back substitution

$$V_{IN}+1.5 = \frac{1.225}{\tanh^{1/2}(0.9)} \rightarrow V_{IN} = -1.5+1.45 = -0.05\text{V}$$

37.4

CHAPTER 37 (CONT)



37.5 $V_{OH} = V_{DD} - 3V_{SBD,GaAs}(ON) = 0.6\,V$

$V_{IL} = V_{T,0} = -1.5V$

$V_{OL} = -3V_{SBD,GaAs}(ON) = -2.4V$

THE EQS TO SOLVE ARE:

$$\beta_L V_{T,L}^2 \tanh \alpha_L V_{DS,L} \cong \beta_0 (V_{IN} - V_{T,0})^2 \tanh \alpha_0 V_{DS,0} + \beta_C V_{T,C}^2 - \beta_F (V_{GS,F} - V_{T,0})^2$$

and

$$\frac{\alpha_L V_{T,L}^2}{\cosh^2 \alpha_L V_{DS,L}} + \frac{\frac{\beta_0}{\beta_L}\alpha_L (V_{IN} - V_{T,0})^2}{\cosh^2 \alpha_0 V_{DS,0}} = 2\,\frac{\beta_0}{\beta_L}(V_{IN} - V_{T,0}) \tanh \alpha_0 V_{DS,0}$$

where $V_{DS,L} = V_{DD} - (V_{OUT} + 3\,V_{SBD,GaAs}(ON))$

and $V_{DS,0} = V_{OUT} + 3V_{SBD,GaAs}(ON)$

Substituting into the EQS YIELDS

$$500(1.5)^2(1) = 1000(V_{IN}+1.5)^2 \tanh \alpha_0 V_{DS_0} + 100\,(1.5)^2 - 100(0.8+1.5)^2 \quad (1)$$

and

$$\frac{1000}{500}\,\frac{2\,(V_{IN}+1.5)^2}{\cosh^2 2\,(V_{OUT}+2.4)} = 2\left(\frac{1000}{500}\right)(V_{IN}+1.5) \tanh 2\,(V_{OUT}+2.4) \quad (2)$$

CHAPTER 39 (SOLUTIONS)

39.1 ANALYZE THE CIRCUIT TO SEE THAT

V_{OUT} = HIGH FOR V_{INA} = HIGH OR V_{INB} = HIGH

ALSO, when $V_{INA} = V_{INB}$ = HIGH, V_{OUT} = High

and V_{OUT} = LOW FOR $V_{INA} = V_{INB}$ = LOW

THIS GATE PERFORMS XOR

39.2 BY INSPECTION OF THE FIGURE, THE LOGIC OUTPUT IS $\overline{(A+C)(B+D)}$

$V_{OH} = V_{DD}$, $V_{OL} = 2V_{OL}$ (ONE MESFET)

Yes, Fig 39.9

39.3 BY INSPECTION OF THE FIGURE, THE LOGIC OUTPUT IS $\overline{AB+CD}$

$V_{OH} \cong V_{DD} - 3V_{SBD(ON)}$

$V_{OL} = 2V_{OL}$ (ONE MESFET)

39.4

OUTPUT IS $\overline{A+B}$

39.5 OUTPUT IS $\overline{A \cdot B}$

30.4 a) STATIC POWER DISSIPATION

$$P_{DISS} = I_{DD} V_{DD}$$

OUTPUT HIGH STATE : N_0 (OFF) $\Rightarrow I_{DD}(OH) = 0$

OUTPUT LOW STATE : P_0 (OFF) $\Rightarrow I_{DD}(OL) = 0$

$$\therefore \quad I_{DD} = \frac{I_{DD}(OH) + I_{DD}(OL)}{2} = 0$$

$$P_{DISS} = 0$$

b) DYNAMIC POWER DISSIPATION

$$P_{DD} = C_L \nu V_{DD}^2 = 0.08 \times 10^{-12} \times 50 \times 10^{6} \times 5^2$$

$P_{DD} = 100 \mu W$, Total Power Diss $= 100 \mu W$

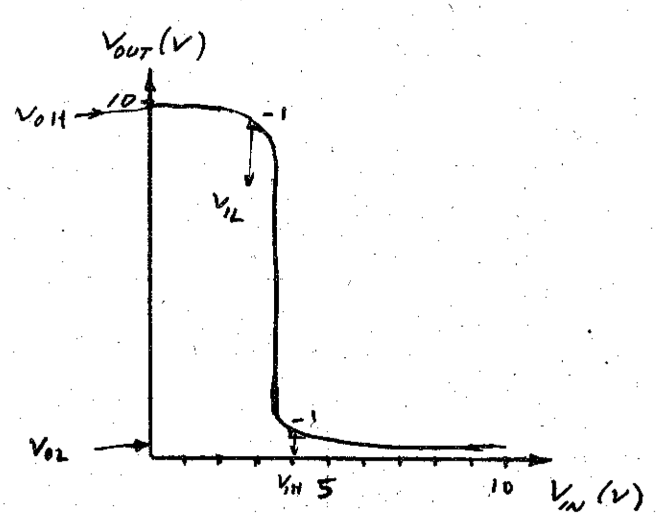
30.5 V_{IN}(LOW); N_1(OFF), P_1(ON), Q_N(OFF), Q_P(SAT)

$$V_{OUT} = V_{DD} - V_{CE,P}(SAT) = V_{OH} = 10 - 0.2 = 9.8V$$

V_{IN}(HIGH); N_1(ON), P_1(OFF), Q_P(OFF), Q_N(SAT)

$$V_{OUT} = V_{CE,N}(SAT) = V_{OL} = 0.2V$$

TO FIND V_{IL} & V_{IH} USE TEXT PROCEDURE



30.6 a) STATIC POWER DISSIPATION

$$P_{DISS} = I_{DD} V_{DD}$$

$$I_{DD} = \frac{I_{DD}(OH) + I_{DD}(OL)}{2} = \frac{0+0}{2} = 0$$

$P_{DISS} = 0$ REGARDLESS OF V_{DD} VALUE

b) DYNAMIC POWER DISSIPATION

$$P_{DD} = C_L \nu V_{DD}^2 = 0.05 \times 10^{-12} \times 25 \times 10^6 \times 10^2$$

$$P_{DD} = 125 \mu W$$

Total Power Diss $= 125 \mu W$

30.7 V_{IN}(LOW); N_I(OFF), P_I(ON), Q_N(ON), Q_P(OFF)

Q_N GIVES LARGE CURRENT INITIALLY

$V_{OUT} = V_{DD} - V_{BE,N}(FA) = V_{OH} = 5 - 0.7 = 4.3V$

V_{IN}(HIGH); P_I(OFF), N_I(ON), Q_N(OFF), Q_P(ON) - PROVIDES PULL-DOWN

$V_{OUT} = V_{BE,P}(FA) = V_{OL} = 0.7V$

LOGIC SWING $= V_{DD} - 2V_{BE}(FA) = 5 - 2(0.7) = 3.6V$

30.8 STATIC POWER DISSIPATION $= I_{DD} V_{DD} = 0 (V_{DD}) = 0$

30.9 V_{OH} IS $V_{DD} - V_{BE,N_2}(FA) = 5 - 0.7 = 4.3V$ (N_3 and P_I ON)

V_{OL} IS $V_{BE,N_1}(FA) = 0.7V$ (N_1 IS ON & N_2 OFF)

30.10 STATIC POWER DISSIPATION $= 0$

30.11 $V_{OH} = V_{DD}$, $V_{OL} = 0$

30.12 STATIC POWER DISSIPATION $= 0$